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Analysis of vegetable production trends, growth rates, instability index, and decomposition in Nigeria

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ABSTRACT

The research examined the trends, growth rates, and instability indices related to the output, harvested area, and yield of major vegetables (Carrot and Turnip; (*Daucus carota* and *Brassica rapa*); Chillies and peppers, dry (*Capsicum spp., Pimenta spp.*), Chillies and peppers fresh (*Capsicum spp., Pimenta spp.*) green; Pineapple (*Ananas comosus*), and Tomato (*Solanum lycopersicum*)) in Nigeria. It also analyzed the decomposition of their production. Utilizing secondary data sourced from the Food and Agricultural Organization (FAO) covering the period from 1961 to 2023, the study revealed fluctuating trends in output, harvested area, and yield of vegetables across the specified timeframe. The exponential growth rate, compound growth rates, Cuddy-Della Valle instability index (CDI) and the Coppock Instability Index (COI) for tomato yield from 1961 – 2023 were identified as -1.59%, -1.63%, 15.48, and 52.64 respectively. For pineapple yield within the same period, the estimates were; 0.51%, 0.43%, 3.13 and 40.58 respectively. For carrot and turnips the estimates were; 0.36%, 0.28%, 2.48, and 39.59 respectively. The instability indices of vegetable yields were relatively low, indicating low activities in the sub-sector in Nigeria. A decomposition analysis of the total effect of vegetable outputs showed that the land area effect accounted for 56.10% for carrot and turnips, 75.08% for chillies and pepper dry, 116.15% for chillies and pepper, green, 65.45% for pineapple, 290.56% for tomato, and 46.93% for other vegetables. The findings suggest that the growth of land area and not improve technology is the major driving force of vegetable output in Nigeria. Consequently, it is recommended that various programs be implemented within the sub-sector to stimulate technology adoption among farmers and potentially enhance both outputs and yields.

Nijerya'da sebze üretim eğilimleri, büyüme oranları, istikrarsızlık endeksi ve ayrışma analizi

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ÖZET

Araştırmada, Nijerya'daki başlıca sebzelerin (Havuç ve Şalgam (*Daucus carota* ve *Brassica rapa*); Acı biber kuru biberler (*Capsicum* spp., *Pimenta* spp.), Acı biberler ve taze yeşil biberler (*Capsicum* spp., *Pimenta* spp.), Ananas (*Ananas comosus*) ve Domates (*Solanum lycopersicum*)) çıktı, hasat alanı ve verimiyle ilgili eğilimler, büyüme oranları ve istikrarsızlık endeksleri incelenmiştir. Ayrıca, üretimlerinin ayrıştırılması da analiz edilmiştir. Gıda ve Tarım Örgütü'nden (FAO) 1961-2023 dönemini kapsayan ikincil veriler kullanılarak yapılan çalışma, belirtilen zaman dilimi boyunca sebzelerin çıktı, hasat alanı ve veriminde dalgalanan eğilimleri ortaya koymuştur. 1961-2023 yılları arasında domates verimi için üstel büyüme oranı, bileşik büyüme oranları, Cuddy-Della Valle istikrarsızlık endeksi (CDI) ve Coppock İstikrarsızlık Endeksi (COI) sırasıyla -%1,59, -%1,63, 15,48 ve 52,64 olarak belirlendi. Aynı dönemdeki ananas verimi için tahminler sırasıyla; %0,51, %0,43, 3,13 ve 40,58 olarak bulundu. Havuç ve şalgam için tahminler sırasıyla; %0,36, %0,28, 2,48 ve 39,59 olarak bulundu. Sebze verimlerinin istikrarsızlık endeksleri nispeten düşük olup, Nijerya'daki alt sektörde düşük faaliyetleri göstermektedir. Sebze çıktılarının toplam etkisinin ayrıştırma analizi, arazi alanı etkisinin havuç ve şalgam için %56,10, acı biber ve kuru biber için %75,08, acı biber ve yeşil biber için %116,15, ananas için %65,45, domates için %290,56 ve diğer sebzeler için %46,93 olduğunu gösterdi. Bulgular, Nijerya'daki sebze çıktısının ana itici gücünün teknolojiyi iyileştirmek değil arazi alanı büyümesi olduğunu göstermektedir. Sonuç olarak, çiftçiler arasında teknoloji benimsemesini teşvik etmek ve potansiyel olarak hem çıktıları hem de verimi artırmak için alt sektörde çeşitli programların uygulanması önerilmektedir.

1.Introduction

According to FAO (2025) and Tadesse (2023), vegetable crops are considered essential staple food components worldwide. The aggregate annual production of vegetable crops has shown steady growth over the years (FAO, 2025). In Africa, vegetable crops are widely cultivated by smallholder farmers and hold great importance (Kadzere et al., 2023). However, the continent currently has the lowest vegetable production and consumption per capita (Schreinemachers et al., 2021; Steenhuijsen et al., 2021). Vegetables are increasingly being recognized as crucial for ensuring food and nutrition security. Researchers such as Schreinemachers et al. (2018) and Akpan et al., (2019b) suggest that vegetable cultivation presents a promising economic opportunity for reducing rural poverty and tackling unemployment in developing countries. Additionally, it plays a key role in enabling farm income diversification (Akpan et al., 2023). Studies have shown that vegetable crops offer a cost-effective source of essential vitamins and minerals crucial for human health maintenance. The World Health Organization (WHO) recommends a minimum daily intake of 200g per person for vegetables, totalling approximately 73kg per year, and 400g per day for fruit and vegetables combined, equating to 146kg per person annually (WHO, 2020). Despite the abundance of research highlighting the health benefits of vegetable consumption, many developing countries still fall short of meeting the WHO's minimum intake standards (Akpan and Okon, 2019a).

In Nigeria, vegetable production plays a significant role in the agricultural sector due to its growing domestic demand and its substantial contribution to achieving the Sustainable Development Goal (SDG) of reducing hunger by 2030 (Akpan et al., 2024a). Nigerian cuisine frequently features vegetables as essential ingredients in dishes such as soups and stews, underscoring their cultural significance. The country's diverse climate environment allows for year-round vegetable production, enabling farmers to grow a wide variety of vegetables, including bitter leaf, carrot, turnip, chillies, African Spinach, waterleaf, African basil, pepper, leafy fluted pumpkin, potatoes, onion, corn, squash, tomatoes, onions, cabbage, okra, and other leafy greens. The vegetable sub sector in Nigeria continues to play a vital role in the country's agricultural landscape. The cultivation of vegetables plays a crucial role in ensuring food security and promoting economic growth (Schreinemachers et al., 2018; Sithole et al., 2023). The production of vegetables is a significant component of the agricultural sector, with an annual output of approximately 137.8 million tons in the country (FAO, 2025). Increased vegetable production, as highlighted by Tadesse (2023), Sithole et al. (2023), and Gebru et al. (2019), has led to improvements in food security and has created employment opportunities for both rural and urban populations. Studies by Mukaila et al. (2022), Akpan et al. (2023), and Akinola et al. (2023) have shown that vegetable production serves as a major source of income for small-scale farmers and those with limited resources in developing countries. The vegetable value chain not only generates income but also helps in reducing poverty and unemployment levels.

Recent studies (Schreinemachers et al., 2018; Akpan and Okon, 2019a) have revealed that vegetable consumption in Sub Saharan Africa falls significantly below the World

Health Organization's minimum standard for human consumption (WHO, 2020). Per capita vegetable intake in this region not only lags behind global averages but is also on a downward trend (Ganry, 2009). The annual consumption of fruits and vegetables in Sub Saharan Africa ranges from 27kg to 114 kg per capita, well below the WHO/FAO recommendation. Nigeria, as highlighted by Kamga et al. (2013), leads in vegetable consumption within the region, with a level at 61.31g per capita per day, still below the required nutritional threshold stipulated by the WHO. To address this gap, there is a pressing need to increase vegetable production in alignment with the goals of the WHO's Fruit and Vegetable Initiative. The federal government of Nigeria has taken steps in recent years to boost agricultural output through various programs and institutional support.

Furthermore, there has been a growing recognition of the health benefits of consuming vegetables in the country. This has led to various intervention programs being implemented by individuals, groups, organizations, and communities to enhance vegetable production. Notably, the cultivation of popular leafy vegetables such as water leaf, tomato, chilies pepper, fluted pumpkin, bitterleaf, and Amaranths plays a significant role in the livelihood activities of rural communities. Vegetable cultivation has emerged as a preferred crop enterprise for youth agro-entrepreneurship and development programs in several states in Nigeria due to its short gestation period, high technical efficiency, nutritive value, gross margin, demand, and affordability (Akpan et al., 2018 and Akpan et al., 2022, Edet and Akpan, 2025). The cultivation of vegetables is considered as one of the potent poverty reduction strategies especially among the resource poor rural women in Nıgeria (Akpan et al., 2019b). While the potential for vegetable cultivation in Nigeria is promising, there are challenges that hinder agricultural development in the country. These challenges include policy inconsistency, weak marketing systems, high input costs, and inadequate infrastructure.

In light of the importance of vegetables and their consistently low per capita consumption in many developing countries, numerous researchers have conducted analyses on the production trends of vegetables. In India, studies by Lalenpuii et al. (2024), Vanitha et al. (2021), and Sethi et al. (2024) have shown a substantial growth rate in production, land areas, and yields for various vegetable crops over different time periods. These studies employed the coefficient of variation, Cuddy-Della Valle Index analysis, and Coppock Instability Index, with results indicating a moderate level of instability in the output, land area, and yield of vegetables in India. The examination of the decomposition analysis revealed that the increase in land expansion played a significant role in driving vegetable output in India. In a separate study, Mathobo et al. (2024) from South Africa assessed the growth rate and instability of area, production, yield, consumption, import and export of dry beans from 1970 to 2019. The findings showed a decrease in the average growth rate of land area, production, and export of dry beans by 1.497%, 0.472%, and 0.282% respectively. Other scholars, including Liverpool-Tasie et al. (2023), Schreinemachers et al. (2023), and Faye et al. (2023), have documented discrepancies in the outputs and yields of vegetables across various African countries. In Nigeria, a number of empirical studies have been carried out to analyze

trends, growth rates, instability indices, and decomposition of different arable crops. For instance, Ochoche et al. (2022), Ikuemonisan et al. (2022), Adebayo (2023), and Akpan et al. (2024b, 2025a, 2025b) have all conducted research focusing on these aspects, revealing fluctuating outputs, land areas, and yields over time. The decomposition analyses of these studies have indicated that land area plays a dominant role in total production of these crops. However, there is a notable gap in similar studies concerning vegetable crops in Nigeria, despite their increasing significance.

Given the limited availability of empirical research on historical trends and growth rates of output, land usage, and yields of major vegetable crops in the country, this study is deemed essential due to the significant impact of vegetable crops on the nation's economy. Analyzing the trends, growth rates, and decomposition of vegetable crop production, cultivated/harvested areas, and yield components is crucial for achieving the desired growth in this sub-sector. Consequently, the study was specifically designed to examine the trends, growth rates, instability indices and decomposition structure of selected vegetable crops in Nigeria spanning from 1961 to 2023.

2. Materials and Methods

2.1. Study Area and Data Source

The study was conducted in Nigeria. The country is endowed with abundant agricultural, marine, and forest resources. The richness of natural resources allows for the cultivation of a wide range of agricultural products. More than sixty percent of the population is involved in agricultural activities, including the production of cassava, groundnuts, oil palm, cotton, sugarcane, rubber, cocoa, rice, maize, aquaculture and artisanal fishing, coconut, livestock, yams, various beans and legumes, sorghum, carrots, and a variety of vegetables, among others. The study made use of secondary data sourced from Food and Agricultural Organization (FAO) extended from 1961 to 2023.

2.2. Analytical Techniques

The study calculated growth rates, instability indices and decomposition of vegetables in Nigeria. The details of the calculations are presented below:

2.2.1. Exponential Growth Rate

In measuring the exponential growth rate of vegetable production, harvested area, and yield, the following equation were defined in accordance with Akpan et al., (2025a),

$$log_e(V_o, V_a, V_y) = \alpha_0 + \alpha_1 t + U_t \quad (1)$$

Where, V_o, V_a, V_y are the output of vegetable in ton, harvested area in hectare and yield in ton/ha respectively in a given year. Variable "t" represents the time variable or trend measured in years. The choice of the exponential growth rate was based on the assumption that the vegetable output, harvested area and yield would likely exhibit exponential growth patterns over the years as a result of various intervention policies implemented by the federal government to boost the subsector's productivity. The exponential growth rate (EGR) is as specified in equation 2.

$$EGR_t = (e^{\alpha_1} - 1)\ x\ 100$$
(2)

Where "EGRt" is the measure of exponential growth rate for a specified variable express in a percentage. The OLS technique was used to estimate equation 1 from which the required parameter α_1 $w$as obtained. An exponential growth rate characterizes the rapid increase of a quantity over time, where the rate of change is directly proportional to the quantity itself. This implies that the rate of increase corresponds directly with the current magnitude of the quantity. Consequently, a greater growth rate results in a larger quantity being measured and produces a steeper curve.

2.2.2. Annual Compound Growth Rate

Compound annual growth rate (CGR) measures the annualized growth rate for compounding values over a given time period. The CGR smoothed the effect of volatility of periodic values that can render arithmetic means less meaningful. The rate represents the rate of return that an investment would need to have every year in order to grow from its beginning balance to its ending balance, over a given time interval. The study assumes that, the annual growth in production, harvested area and yield of vegetable subsector were as a result of investment done over the years by stakeholders in the subsector. Hence, a simple business CGR was estimated for the production, harvested area and yield of respective vegetables as thus:

$$\boldsymbol{CGR} = \left(\left(\frac{V_n}{V_f}\right)^{\frac{1}{n}} - 1\right) * \ 100 \qquad (3)$$

Where ''n'' represents the total number of years considered, V_f represent the initial or the first year value and V_n is the last year value of the variable considered. The rate is expressed as a percentage. A higher value of CGR represents a higher annual growth rate and a lower value, a lower annual growth rate.

2.2.3. Coefficient of Variability (COV)

The COV is a prominent index used for assessing variability and instability within a series. It quantifies the relative dispersion of data around the mean value. However, it is important to note that the COV tends to overestimate instability in time series with long-run trends and does not adequately account for the trend component inherent in the data. A higher COV indicates greater variability, while a lower COV suggests less variability.

$$COV = \frac{\text{standard deviation}}{\text{mean}} \qquad (4)$$

2.2.4. Cuddy-Della Valle index (CDI)

The Cuddy Della Valle index removes trend effects from annual series, providing a clear indication of instability direction (Cuddy and Della Valle, 1978). By utilizing the adjusted coefficient of determination, it eliminates the impact of trends on the coefficient of variation (COV), resulting in a superior measure of instability (Wasem,

2001). A low value of this index suggests low instability in the series, whereas a high value indicates the opposite. The formula for calculating this index is as follows:

$$CDI = COV\sqrt{1 - \bar{R}^2} \quad (5)$$

Where COV is the coefficient of variation in percent, and $\bar{R}^2$ denotes the adjusted coefficient of determination obtained from the linear time trend regression on output, harvested area and yield of vegetables in the country. The degrees of instability are classified into three ranges: Low instability (from 0 – 15); medium instability (greater than 15, but less than 30) and high instability (>30).

2.2.5. Coppock Instability Index (COI)

The Coppock (1962) instability index measures instability by utilizing log variance methodology. A greater Coppock instability index indicates heightened instability, while a lower index signifies lower instability. It is given as:

$$\text{Coppock Instability Index (COI)} = \text{Antilog}\left(\sqrt{\text{logV}} - 1\right)\text{x } 100 \quad (6)$$

Where,

$$logV = \frac{1}{N-1}\sum(logX_{t+1} - logX_t - M)^2 \quad (7)$$

$$M = \frac{1}{N-1}\sum(logX_{t+1} - logX_t) \quad (8)$$

Note,

X_t = Time series or variable under consideration (e.g. log of output/area/yield) in period t.

M = Mean value of the first differences of logarithm

N = Total number of observations

V = Value of Variance log obtained by substituting the values of first differences and M in equation 7.

2.2.6. Vegetable Production Decomposition

The instability indices does not consider the proportional impact of harvested area and yields on the respective vegetable crops. The decomposition analysis isolate the effects of yield, harvested area and the interaction effect from the total production. The process is shown as thus:

Total effect = Area effect + Yield effect + Interaction effect

$$D = \frac{A_0\Delta Y * 100}{\Delta P} + \frac{Y_0\Delta A * 100}{\Delta P} + \frac{\Delta Y\Delta A * 100}{\Delta P} \quad (9)$$

Where,

A_0 = Area in the base year

ΔA = Current harvested area minus the base area

Y_0 = Yield in the base year

ΔY= Current yield minus the base yield

ΔP = Current production minus base production

All analyses specified in the study are done for three (3) periods i.e. 1961–1985, 1986–2023 and 1961 – 2023. These periods represent the major policy eras in Nigeria. The vegetable crops considered were; Carrot and Turnip; (*Daucus carota* and *Brassica rapa*); Chillies and peppers, dry (*Capsicum spp., Pimenta spp*.), Chillies and peppers (*Capsicum spp., Pimenta spp*.) green; Pineapple (*Ananas comosus*), Tomato (*Solanum lycopersicum*), and other Vegetables. The choice of the vegetables was based on the availability of data.

3.Results and Discussion

3.1. Trend Analyses

The trends for vegetables' output from 1961 to 2023 in Nigeria is presented in figure 1. The outputs of the specified vegetables displayed a fluctuating pattern, with notable irregular peaks and troughs over the examined period. For instance, carrot and turnip outputs assumed a zero growth from 1961 to 1988. A depression occurred in 1993 and 2011, the rest of the periods assume an average upward trend. A steady upward trends were observed for dry chillies and peppers, green chillies and peppers, pineapple, tomato and other vegetables in most of the periods considered. The fluctuation in vegetable outputs in the country was observed to have an average upward trend during the pre-Structural Adjustment Programme (SAP) period spanning from 1961 to 1985. Most of the conspicuous troughs in the trends occurred during the SAP period of 1986 to 1993 and post-SAP period of 1994 to 2023.

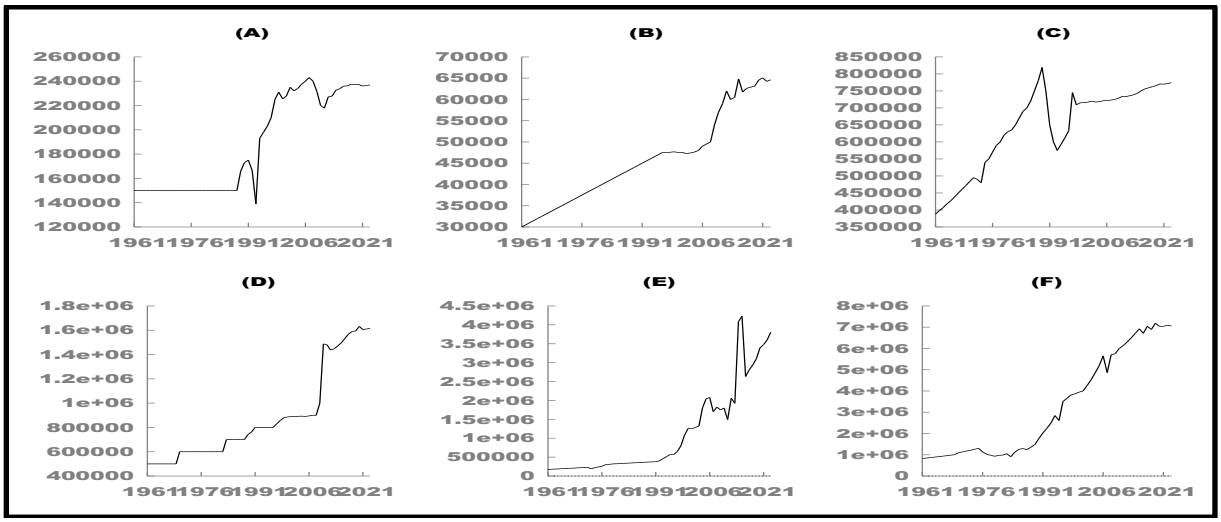

Figure 1. Trend in vegetables production (tons) in Nigeria (1961 – 2023). Where (A) = Carrot and Turnip; (B) = Chillies and peppers, dry; (C) = Chillies and peppers, green; (D) = Pineapple; (E) = Tomato; (F) = other vegetables.

However, the last four years of the time frame considered (from 2020 – 2023) witnessed a consistent upward growth in all vegetable outputs examined. The trends observed in vegetable outputs depict the fact that, the country has injected concerted effort to grow vegetables over the years. The observations found are similar to those reported by Ochoche et al., (2022), Ikuemonisan et al., (2022), Adebayo (2023), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b) for other arable crops.

Figure 2 illustrates the trends in the harvested land area dedicated to vegetable crops examined in this study. These trends predominantly mirror the output patterns identified throughout several time periods. Notable fluctuations occurred particularly during the SAP and Post SAP phases. The parallels between the trends in harvested area and output for vegetable crops can be linked to various government policies concerning arable crop production that have been enacted over the years. A significant number of these policies aimed to enhance vegetable crop production primarily through land expansion, rather than the adoption of advanced technologies. Consequently, the increases in output observed during most of the analyzed periods are directly attributable to the expansion of cultivable land area.

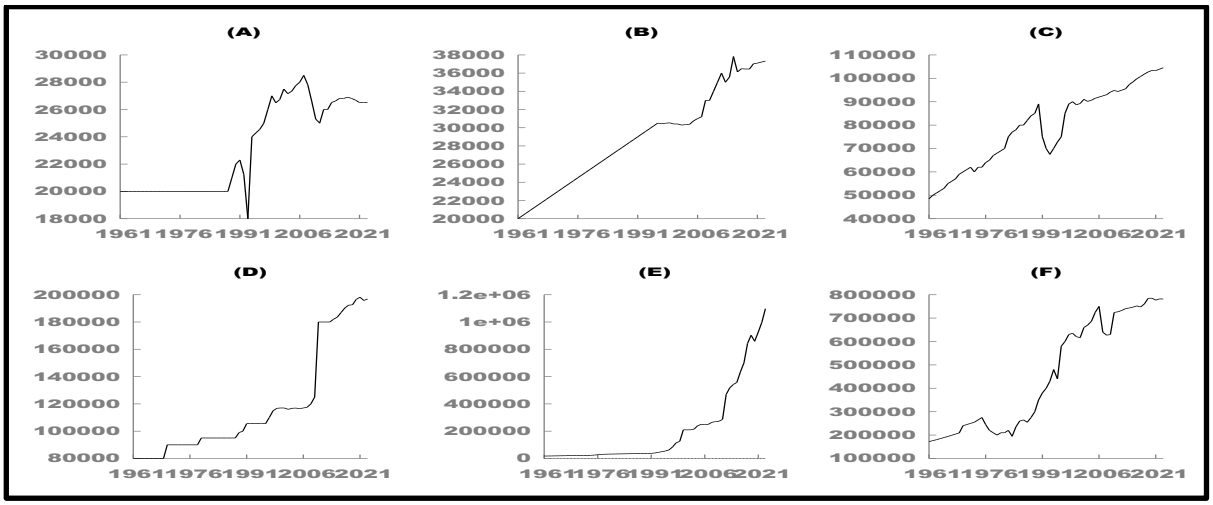

Figure 2. Trend in harvested area (hectare) of vegetables in Nigeria (1961 – 2023). Where (A) = carrot and turnip; (B) = chillies and peppers, dry; (C) = chillies and peppers, green; (D) = pineapple; (E) = tomato; (F) = other vegetables.

The data indicates a consistent increase in the area of land harvested for all vegetable crops studied from 1961 to 2023. This ongoing expansion of agricultural land suggests a persistent issue of low productivity affecting the subsector throughout the years in the country.

Figure 3 illustrates the trends in vegetable crop yields, which have demonstrated variability when compared to trends observed in output and harvested area during the same period. Notably, only carrots, turnips, dry chillies and peppers, pineapples, and other vegetables displayed an average upward trend during the study's timeframe. In contrast, green chillies, peppers, and tomatoes exhibited an average downward trend within the analyzed period.

The fluctuations in yield response among designated vegetable crops over time are considerably influenced by agricultural policies and programs in the country. These policies play a crucial role in aligning with economic demands and capabilities, which ultimately determine the trends in vegetable yields nationally. For instance, in Nigeria, historical agricultural policies have largely overlooked vegetable crop production, directing focus instead toward non-vegetable arable crops such as cassava, yam, and groundnut. Consequently, farmers have tended to prioritize these staple crops over

vegetable production, rendering the adoption of innovations in the vegetable sector particularly difficult, especially prior to the era of the Structural Adjustment Program (SAP).

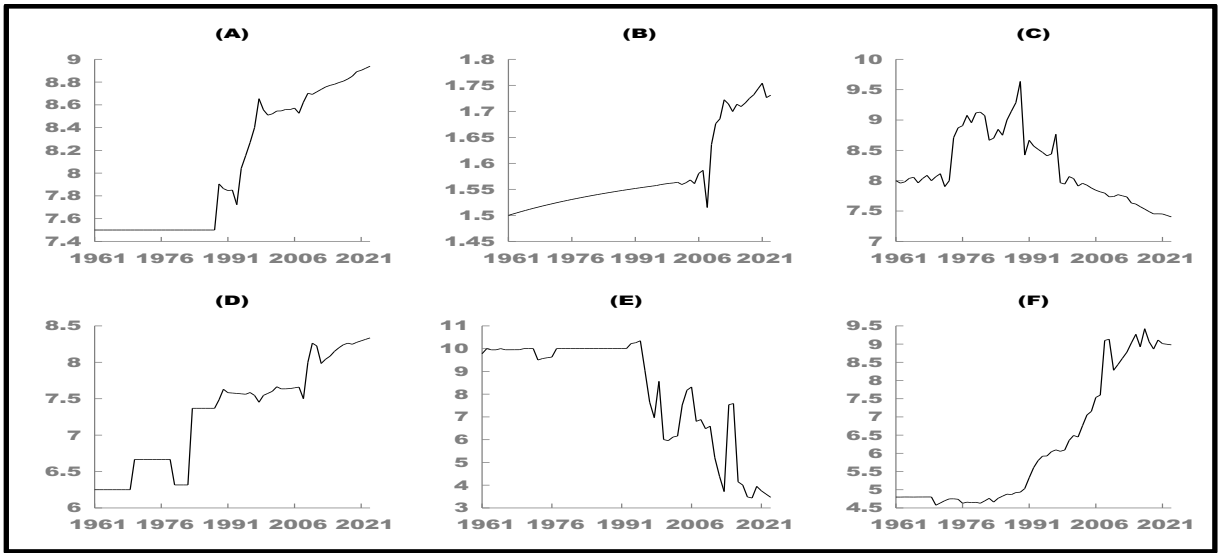

Figure 3. Trend in Yield (ton/ha) of vegetables in Nigeria (1961 – 2023). Where (A) = Carrot and Turnip; (B) = Chillies and peppers, dry; (C) = Chillies and peppers, green; (D) = Pineapple; (E) = Tomato; (F) = Other Vegetables.

In recent years, however, there has been a marked increase in the production and yield of certain vegetable crops within the country. Crops such as carrots, turnips, pineapples, and dry chillies have demonstrated significant improvements in both output and yield over the last five years. This progress can be attributed to multiple initiatives undertaken by the government and stakeholders in the agricultural sector aimed at promoting awareness of the nutritional and economic benefits associated with these crops. Nonetheless, the yields of exotic vegetables, including tomatoes and green chillies, continue to struggle in adapting to local conditions due to insufficient advanced technology to enhance their yields. These yield observations align with the findings of Ikuemonisan et al. (2022), Adebayo (2023), Akpan et al. (2024b), Akpan et al. (2025a), and Akpan et al. (2025b).

3.2. The Compound Growth Rate and Instability Index in Output, Area and Yield

The estimated coefficients of variation (COV), exponential growth rate (EGR), compound growth rate (CGR), Cuddy-Della Valle instability index (CDI), and Coppock instability index (COI) associated with the output, harvested area, and yield of vegetable crops in Nigeria for the periods 1961–1985, 1986–2023, and 1961–2023 are presented in Tables 1, 2, and 3, respectively.

3.2.1. Growth rates and Instability Indices in Output of Vegetable Crops

The analysis estimates that capture the coefficient of variation, exponential growth rate, compound growth rate, and instability index of vegetable output in the specified timeframe are discussed below:

Carrots & turnips: The production levels of carrots and turnips remained stable during the initial period from 1961 to 1985, resulting in a coefficient of variation (COV), exponential growth rate (EGR), and compound growth rate (CGR) of zero percent. In the subsequent period from 1986 to 2023, there was a slight increase in COV and single-digit values for EGR and CGR, accompanied by low instability indices. The overall analysis spanning from 1961 to 2023, showed a minimal coefficient of variation in output (14.73%), as well as low EGR (1.04%) and CGR (0.73%). These findings suggest that there were few significant changes or interventions in the subsector during this time frame that significantly affected carrot and turnips output in the country.

Chillies and peppers, dry and green: The output of both dry and green chilies and peppers demonstrated a consistent trend of positive growth with low instability rates throughout the analyzed period. It was noted that the growth rates and coefficient of variation (COV) were higher during the 1961-1985 period compared to the 1986-2023 period. This suggests that there were fewer significant activities affecting the output of these subsectors during the period of analysis.

Table 1. Growth rates and Instability Indices in vegetable Outputs (ton) in Nigeria.

	Vegetables					
Indicator	Carrots & turnips	Chillies and peppers, dry	Chillies & peppers, green	Pineapple	Tomato	other vegetables
			1961 – 1985 (Pre- SAP Period)			
Mean	150000	36000	530120	576000	251640	1029800
COV (%)	0.000	10.222	18.647	11.516	24.734	13.354
EGR (%)	0.000	1.407	2.551	1.411	3.196	0.877
CGR (%)	0.000	1.355	2.388	1.355	2.788	1.684
CDI	0.000	0.00	2.681	5.220	11.211	12.062
COI	36.792	40.781	44.335	41.257	46.890	41.954
			1986 – 2023 (SAP and Post-SAP Period)			
Mean	213911	52571	721599	1094036	1708209	4672701
COV (%)	14.727	15.049	7.605	32.288	70.135	43.025
EGR (%)	1.181	1.266	0.334	2.670	7.474	4.768
CGR (%)	1.210	1.109	0.190	2.225	6.440	4.567
CDI	8.748	5.063	6.850	12.596	26.428	7.782
COI	43.344	42.618	39.869	50.256	84.532	63.789
			1961 – 2023 (Overall period)			
Mean	188550	45995	645615	888466	1130206	3227106
COV (%)	21.119	22.738	18.649	42.329	103.717	73.637
EGR (%)	1.044	1.222	0.969	2.052	5.694	4.353
CGR (%)	0.728	1.225	1.102	1.879	4.999	3.464
CDI	9.159	5.084	9.380	17.319	51.471	24.043
COI	45.443	46.096	45.218	54.224	104.869	83.006

Source: computed by authors.

Pineapple, tomato and other vegetable: The vegetable crops analyzed exhibited positive Exponential Growth Rate (EGR) and Compound Growth Rate (CGR) over the study period. This indicates that the production of pineapple, tomato, and other vegetables increased during the analysis period. The rate of growth was found to be higher in the pre-Structural Adjustment Program (Pre-SAP) era compared to the SAP and post-SAP periods. The computed Cuddy-Della Valle index (CDI) and Coppock Instability Index (COI) indicated moderate instability for pineapple and other vegetable outputs, while tomato output showed high instability. The coefficient of variation (COV)

was relatively high for the specified vegetable outputs from 1961 to 2023. These results imply that various interventions were implemented to boost the production of these crops during the study period. Similar fluctuations observed in the indices of vegetable output instability have been documented in numerous studies conducted in developing countries, as highlighted by Ochoche et al., (2022), Liverpool-Tasie et al., (2022), Schreinemachers et al., (2022), Adebayo (2023), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b).

3.2.2. Growth Rates and Instability Indices in Harvested Area (ha) of Vegetable Crops in Nigeria

Similarly, the analysis conducted provides estimates of various statistical quantities that characterize the coefficient of variation, growth rate, and instability index of the harvested area of vegetable crops within the specified timeframe.

Carrots & turnips: The study reveals that key indicators related to the harvested area exhibit a distribution pattern akin to output indicators. Specifically, the coefficient of variation (COV), the exponential growth rate (EGR), and the compound growth rate (CGR) all presented as zero between 1961 and 1985. However, these indicators displayed a positive trend in subsequent periods, signifying a consistent upward trend in the harvested land area of carrots and turnips over the years. It is noteworthy that the instability indices, the CDI and COI remained low across all periods, indicating low instability in the harvest area of carrots and turnips during the specified timeframe.

Table 2. Growth rates and Instability Indices in harvested land area (ha) of vegetable in Nigeria

Indicator	Vegetables					
	Carrots & turnips	Chillies and peppers, dry	Chillies & peppers, green	Pineapple	Tomato	other vegetables
1961 – 1985 (Pre- SAP Period)						
Mean	20000	36000	62460	87800	25364	217795.2
COV (%)	0.000	9.356	14.290	7.181	24.162	13.663
EGR (%)	0.000	1.286	1.919	0.919	3.177	0.969
CGR (%)	0.000	1.238	2.022	0.690	2.696	1.664
CDI	0.000	0.00	2.814	2.708	6.966	12.123
COI	36.792	40.221	42.390	39.565	46.675	42.135
1986 – 2023 (SAP and Post-SAP Period)						
Mean	25218	32337	90076	138797	336218	611317
COV (%)	10.645	10.144	11.314	28.182	95.219	27.553
EGR (%)	0.742	0.873	0.905	2.332	10.796	2.708
CGR (%)	0.743	0.807	0.706	1.936	9.449	2.886
CDI	7.498	2.927	5.663	10.790	36.991	11.250
COI	41.265	40.674	41.428	48.321	117.160	51.683
1961 – 2023 (overall period)						
Mean	23147	28870	79117	118560	212863	455158
COV (%)	14.277	17.957	21.086	33.324	136.707	51.496
EGR (%)	0.679	0.992	1.165	1.540	7.406	2.951
CGR (%)	0.448	10.995	1.226	1.439	6.741	2.431
CDI	7.065	2.545	5.521	15.040	79.422	16.293
COI	42.418	44.175	45.940	49.662	143.692	64.516

Source: computed by authors.

Chillies and peppers, dry and green: The harvested areas of dry and green chillies and peppers showed consistent growth over the specified period, with both EGR and CGR

indicating positive trends. This suggests that the harvested areas of these vegetables increased steadily on average throughout the analysis timeframe. However, the growth rates were notably higher before the implementation of SAP, declining slightly during and after this period. The calculated values for COV, CDI, and COI indicate a low level of variability in the cultivated areas of dry and green chillies and peppers over the course of the analysis. This implies that there were only marginal positive changes in the harvested areas of these vegetables during the specified timeframe.

Pineapple, tomato and other vegetable: The harvested areas of pineapple, tomato, and other vegetables exhibited positive growth rates over the specified time periods. The estimated EGR and CGR values were positive from 1961 to 1985 and showed even higher values from 1986 to 2023. This indicates a consistent increase in the harvested areas of these vegetables throughout the review period. The calculated Cuddy-Della Valle index (CDI) and Coppock Instability Index (COI) indicated moderate instability for pineapple and other vegetable harvested areas, and a high instability rate for tomato harvested areas. The coefficient of variation (COV) for the vegetable harvested areas was relatively high from 1961 to 2023. These findings suggest that various activities or programs were implemented in these crop enterprises during the analysis period, leading to the expansion of their cultivated land areas. Comparable findings have been reported for various crops by Vanitha et al., (2021), Ochoche et al., (2022), Ikuemonisan et al., (2022), Adebayo (2023), Akpan et al., (2024b), Lalenpuii et al., (2024), Akpan et al., (2025a), Akpan et al., (2025b), and Sethi et al., (2024).

3.2.3. Growth Rates and Instability Indices in Yields (ton/ha) of Vegetable Crops

Estimates for growth rates, coefficient of variation, and instability index of vegetable crop yields were also calculated.

Carrots & turnips: The yield remained stable from 1961 to 1985, while there was a slight increase in yield from 1986 to 2023 with low instability indices (COI and CDI). Analysis of aggregate data from 1961 to 2023 showed that the yield of carrots and turnips grew by 0.36% for EGR and 0.28% for CGR.

Throughout the analysis period, COV, CDI, and COI remained relatively low. Compared to Egypt (EGR = 0.83% and CGR = 0.76%), Nigeria had a lower growth rate in carrot and turnip yield, but higher than South Africa (EGR = -0.122% and CGR = -0.13%) (FAO, 2025). These findings suggest that improved technologies are needed for carrot and turnip production in Nigeria to increase production and yield. This would also help position the country in a more competitive and sustainable advantage relative to other African nations.

Chillies and peppers, dry and green: The analysis reveals a consistent positive annual growth in the yield of dry chillies and peppers over the study period. From 1961 to 1985, the estimated values of EGR and CGR stood at 0.12%, and 0.12% respectively, increasing to 0.39% for EGR and 0.30% for CGR from 1986 to 2023. The aggregate data for the entire period (1961-2023) shows a growth rate of 0.23% for both EGR and CGR. However, these growth rates were lower than those observed in other countries such as

Cameroon (EGR = 1.50%; CGR = 1.27%), Egypt (EGR = 0.62%; CGR = 0.57%), Ghana (EGR = 3.39%; CGR = 2.67%), and South Africa (EGR = 1.00%; CGR = 1.17%) within the same period.

Table 3. Growth rates and Instability Indices in yield (ton/ha) of vegetables in Nigeria

	Vegetables					
	Carrots & turnips	Chillies and peppers, dry	Chillies & peppers, green	Pineapple	Tomato	other vegetables
1961 – 1985 (Pre- SAP Period)						
Mean	7.500	1.524	8.440	6.545	9.911	4.731
COV (%)	0.000	0.883	5.536	5.545	1.598	1.579
EGR (%)	0.000	0.119	0.620	0.488	0.018	-0.091
CGR (%)	0.000	0.116	0.359	0.661	0.090	0.020
CDI	0.000	0.0743	3.219	4.230	1.627	1.459
COI	36.792	37.119	38.875	38.824	37.392	37.379
1986 – 2023 (SAP and Post-SAP Period)						
Mean	8.443	1.618	8.059	7.798	7.009	7.270
COV (%)	5.166	4.928	7.033	4.098	34.552	22.057
EGR (%)	0.435	0.389	-0.566	0.330	-2.999	2.003
CGR (%)	0.463	0.299	-0.513	0.284	-2.749	1.634
CDI	2.085	2.313	2.918	1.822	15.474	6.007
COI	38.797	38.629	39.388	38.320	5 53.874	46.230
1961 – 2023 (Overall period)						
Mean	8.069	1.581	8.210	7.301	8.160	6.262
COV (%)	7.115	4.906	6.800	9.628	28.890	28.132
EGR (%)	0.363	0.227	-0.193	0.505	-1.594	1.362
CGR (%)	0.279	0.228	-0.123	0.433	-1.632	1.009
CDI	2.480	2.496	5.881	3.131	15.482	11.339
COI	39.490	38.594	39.341	40.584	52.637	48.032

Source: computed by authors.

On the contrary, the growth rates of green chillies and pepper showed a slight positive trend from 1961 to 1985. However, there was an average annual decrease in both yields during the periods of 1986 to 2023 and for the overall period of 1961 to 2023. This indicates a consistent decline in yields of green chillies and pepper throughout the analysis. For the entire data set from 1961 to 2023, the estimated EGR and CGR were found at -0.19% and -0.12% respectively. In comparison, Egypt saw improvements in yields with an EGR of 0.19% and CGR of 0.41%, while Ghana had even higher increases with an EGR of 2.24% and CGR of 2.15% (FAO, 2025). The COV, CDI, and COI values were relatively low, indicating consistent low instability in yields for these vegetable crops over the selected time periods. The data suggests that in Nigeria, the production of dry and green chillies and peppers relies more on land expansion rather than advancements in technology. This differs from other African countries such as Ghana, Egypt, and South Africa, where significant technological improvements have been implemented in the production of these vegetable crops.

Pineapple, tomato and other vegetables: The analysis of pineapple yield over the specified timeframe showed a consistent positive marginal increase in growth rate. This indicates a gradual improvement or increase in pineapple yields during the period under review. The instability indicators; CDI, COI, and COV were all low, suggesting relatively low instability in yields and minimal fluctuations in the subunit activities. For

the overall data spanning from 1961 to 2023, the pineapple yield growth rates were 0.51% for EGR and 0.43% for CGR. These rates are notably lower compared to other countries such as Cameroon (EGR = 2.36%, CGR = 0.85%), Cote d'Ivoire (EGR = 0.94%, CGR = 1.73%), and Ghana (EGR = 6.69%, CGR = 5.07%) as reported by FAO in 2025. These findings suggest that Nigeria's pineapple production lags behind several other African countries. It also implies that countries like Ghana and Egypt have adopted advanced technologies in their pineapple production process, surpassing Nigeria in terms of efficiency and output. Despite this, Nigeria's annual growth rate in yield exceeded that of South Africa (EGR = -1.60%, CGR = -1.05%) and Congo (EGR = -0.20%, CGR = -0.14%) (FAO, 2025).

During the period from 1961 to 1985, the growth rates of tomato yield exhibited a marginal positive trend. The coefficient of variation (COV) and instability indices (CDI and COI) of tomato yield were low, suggesting minimal fluctuations. However, from 1986 to 2023, there was a decline in tomato yield with an EGR of -2.99% and CGR of -2.75%, along with moderate instability indices. The negative trend persisted in the aggregate data, with estimated EGR and CGR of -1.59% and -1.63% respectively, and moderate instability indices. These findings indicate a declining trend in tomato yield in Nigeria from 1961 to 2023. The findings indicate that the current technology being used for tomato production in Nigeria is not sufficient to sustain production levels in the present or future. The estimated yields are unable to meet domestic demand and do not position the country competitively in Africa. For example, when compared to other African countries from 1961 to 2023, Nigeria's performance lags behind Ghana (EGR: 0.87%, CGR: 0.71%), Cameroon (EGR: 2.24%, CGR: 2.51%), Congo (EGR: -1.00%, CGR: -0.65%), Egypt (EGR: 2.11%, CGR: 1.65%), South Africa (EGR: 2.09%, CGR: 1.45%), and Cote d'Ivoire (EGR: 0.005%, CGR: 0.068%) (FAO, 2025).

The growth rate trend for yield of other vegetable crops exhibited a consistent positive growth from 1961 to 2023. A detailed analysis indicated that the annual growth rate for yields of other vegetable crops was positive at 1.36% for EGR, and 1.01% for CGR. The CDI and COI metrics indicated a low level of instability in the yield of other vegetables. Interestingly, Nigeria demonstrated a superior performance in the productivity of other vegetable crops compared to several African countries during this period. For example, Nigeria's yield growth rate surpassed that of countries such as Cameroun (EGR = 1.01%, CGR = 0.97%), Egypt (EGR = -2.20%, CGR = -1.50%), Congo (EGR = 0.12%, CGR = 0.07%), South Africa (EGR = -0.30%, CGR = -0.33%) and Cote d' Ivoire (EGR = 0.33, CGR = 0.28) according to data from the FAO in 2025. The results correspond with the conclusions drawn in prior studies on various crops by Vanitha et al., (2021), Lalenpuii et al., (2024), Sethi et al., (2024), Faye et al., (2023), Mathobo et al., (2024), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b).

3.3. Decomposition of Output of Vegetable Crops in Nigeria

The breakdown of vegetable outputs decomposition is detailed in Table 4. The analysis highlights the key components influencing the total effect, including the area effect, yield effect, and interaction effect. It was found that between the years 1961 and

1985, the land area effect played a dominant role in driving variations in the total effect of vegetable outputs. This suggests that the growth in vegetable production during this time frame was primarily driven by the expansion of cultivable land rather than improvements in technology or agricultural practices. Thus, it can be inferred that the government prioritized increasing cultivable land through its various programs without focusing on enhancing vegetable crop yields.

Table 4. Percentage decompositions of area, yield and their interaction effects on vegetable outputs in Nigeria.

	1961 – 1985			
	Yield effect (%)	**Area effect (%)**	**Interaction effect (%)**	**Total effect**
Carrots & turnips	0.00	0.00	0.00	0.00
Chillies and peppers, dry	7.35	90.00	2.65	100.00
Chillies & peppers, green	11.66	80.77	7.57	100.00
Pineapple	44.74	46.87	8.39	100.00
Tomato	2.30	95.53	2.17	100.00
Other vegetables	0.95	98.57	0.48	100.00
	1986 – 2023			
Carrots & turnips	33.13	56.10	10.77	100.00
Chillies and peppers, dry	23.08	68.67	8.25	100.00
Chillies & peppers, green	-236.66	409.25	-72.59	100.00
Pineapple	8.70	81.96	9.34	100.00
Tomato	-6.73	307.84	-201.11	100.00
Other vegetables	19.09	43.71	37.20	100.00
	1961 – 2023			
Carrots & turnips	33.13	56.10	10.77	100.00
Chillies and peppers, dry	13.35	75.08	11.57	100.00
Chillies & peppers, green	-7.49	116.15	-8.66	100.00
Pineapple	14.04	65.46	20.50	100.00
Tomato	-3.13	290.86	-187.73	100.00
Other vegetables	11.69	46.93	41.38	100.00

Source: computed by authors.

During the time frame from 1986 to 2023, the dominance of the land area effect on vegetable production was still evident. The area effect accounted for over 40.00% of the total output in all specified vegetables, offsetting the negative impacts of interaction effects on green chillies and pepper, and tomato enterprises.

An analogous discovery was noted in the combined data spanning from 1961 to 2023, highlighting the significant influence of land area effect on vegetable crop production in Nigeria. The analysis demonstrated that the land area effect accounted for more than 45.00% of the total impact, counteracting any negative effects from interactions, particularly in tomato cultivation. These findings underscore the pivotal role of land area in understanding variations in vegetable production across the country. The finding has a serious implication for a sustainable vegetable production in the country. Giving the rising rural population and associated land pressures, mounting soil degradation and rural poverty in the country; continuous land expansion cannot yield sustainable vegetable production in the long run.

Continuous land expansion would compromise the traditional farrow system, intensify soil infertility and makes it more difficult for smallholder farmers to benefit from yield gains offered by plant genetic improvement. The results corroborate Ochoche

et al., (2022), Ikuemonisan et al., (2022), Adebayo (2023), Akpan et al., (2024b), Akpan et al., (2025a), and Akpan et al., (2025b).

4. Conclusion

The study examined trends, growth rates, and instability index linked to vegetable crops production, harvested area, and yield in Nigeria spanning from 1961 to 2023. A decomposition analysis was conducted to separate the total output effect into area effect, yield effect, and interaction effect. The analysis was segmented into three distinct sub-periods: 1961–1985, 1986–2023, and the complete period from 1961 to 2023. The trend analysis revealed fluctuations in the output, harvested area, and yield of vegetables across all sub-periods and the aggregated period. The calculated exponential growth rate (EGR) and compound growth rate (CGR) for vegetable outputs and harvested areas remained positive throughout the analysis period, indicating an increase in these factors over time. In contrast, the CGR and EGR of green chillies and pepper, and tomato exhibited decreasing trends. Conversely, other specified vegetables such as carrot, turnips, dry chillies, pepper, and pineapple displayed an upward trend in yield. The calculated Cuddy-Della Valle index (CDI) and Coppock Instability Index (COI) for pineapple and other vegetables indicated a moderate level of instability, whereas the tomato enterprise showed high instability. These results suggest that various initiatives were implemented, leading to significant fluctuations in output and harvested areas of these vegetables. However, when considering the yield component, most specified vegetables had low instability levels except for tomatoes, which showed moderate instability.

Decomposition analyses indicate that throughout various time periods from 1961 to 2023, the significant growth in total vegetable crop production in the country was primarily driven by the expansion of land area rather than improvements in yield. This suggests that the observed increases in vegetable crop production are largely attributed to the increase in cultivable land, with yield and other factors playing a minor role. To enhance yield performance and overall output, it is imperative for stakeholders within the vegetable sub-sector to adopt advanced technologies and reduce their dependency on land area expansion. By implementing additional initiatives, the sub-sector can promote increased activity and cultivate a more sustainable approach towards enhancing yield contributions. Also incorporating vegetable production into youth development programs in the country is essential to promoting youth participation in vegetable production. The utilization of hydroponic systems and greenhouses for vegetable production is strongly encouraged, as these technologies can attract more young people to engage in vegetable production. Additionally, enhancing access to high-quality planting materials, financial assistance, and land for vegetable farmers can significantly boost activities within the sub-sector and enhance yields.

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Author Contribution
All authors contrıbuted equally ın the conception and development of the entire research work.

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